

## Session: Limits and sources of predictability

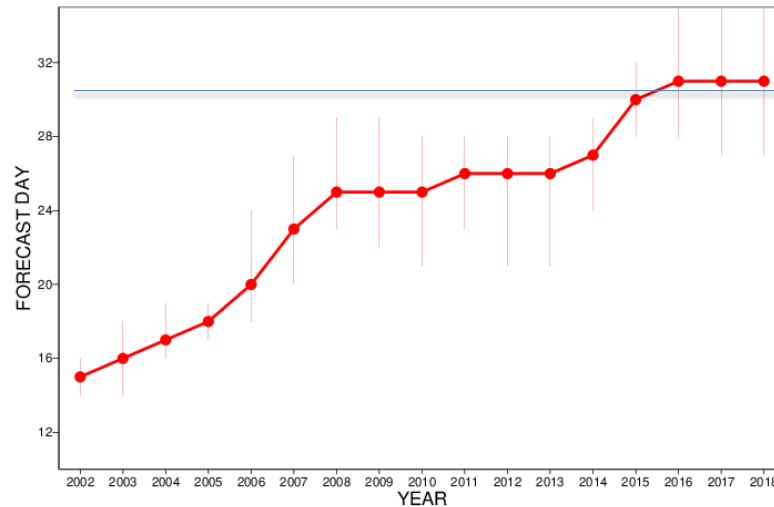
### Discussion Questions:

- ▶ What are the current estimates of the limit of precipitation predictability, and how much of those are not yet realized as prediction skill?
- ▶ What are the key biases most likely to impact precipitation prediction over the US at different time scales? What is the relationship between biases in a model and its prediction skill?
- ▶ What existing and new observations and observation-modeling integration activities can be exploited or organized to diagnose and address the biases? What new methodological and technological advances can be brought to bear?
- ▶ Which diagnostics and metrics can be used to quantify prediction skill and predictability limits? Which metrics can be used to detect small advances on precipitation forecasts for long term monitoring of progress?

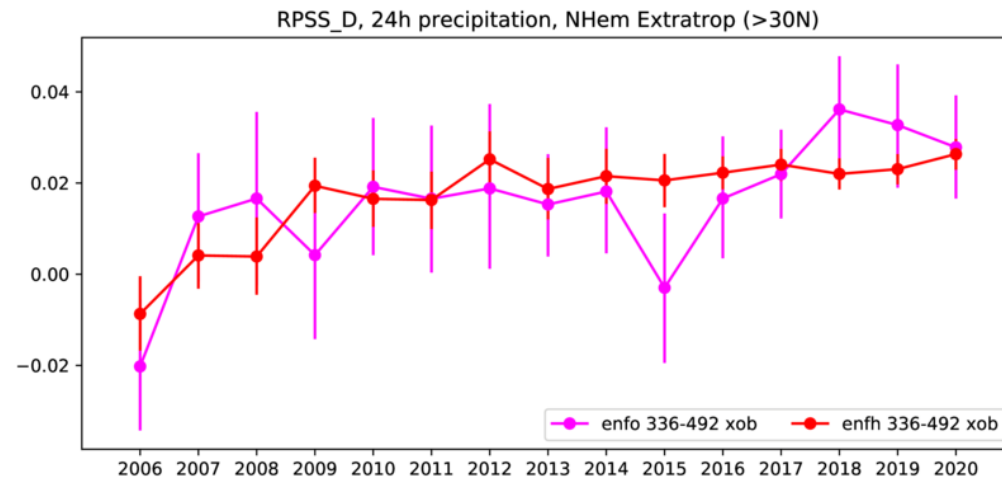
# Evolution of skill scores

Prediction of some important sources of S2S predictability, such as the MJO, has improved significantly over the past decade, but not the prediction of precipitation over the northern Extratropics.

**MJO RMMS**  
Bivariate correlation reaching 0.6

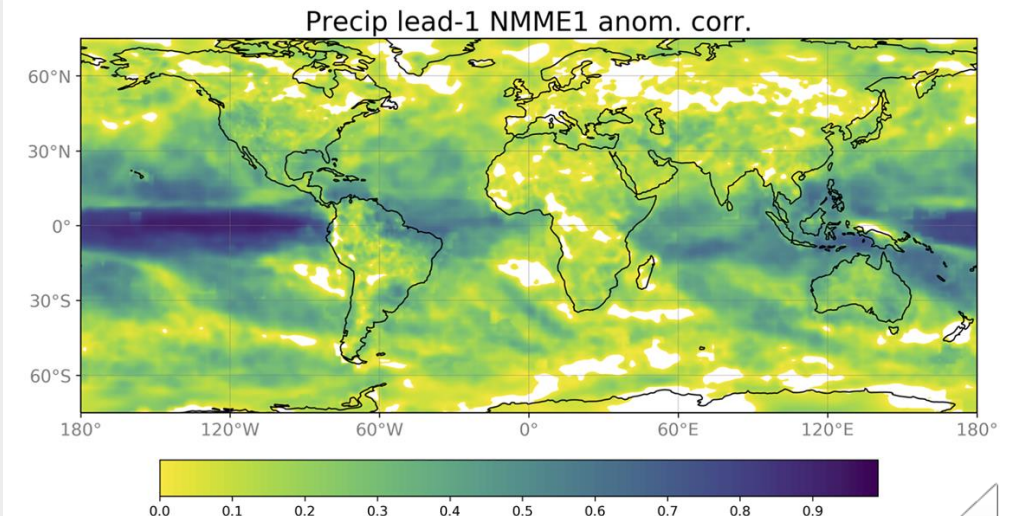
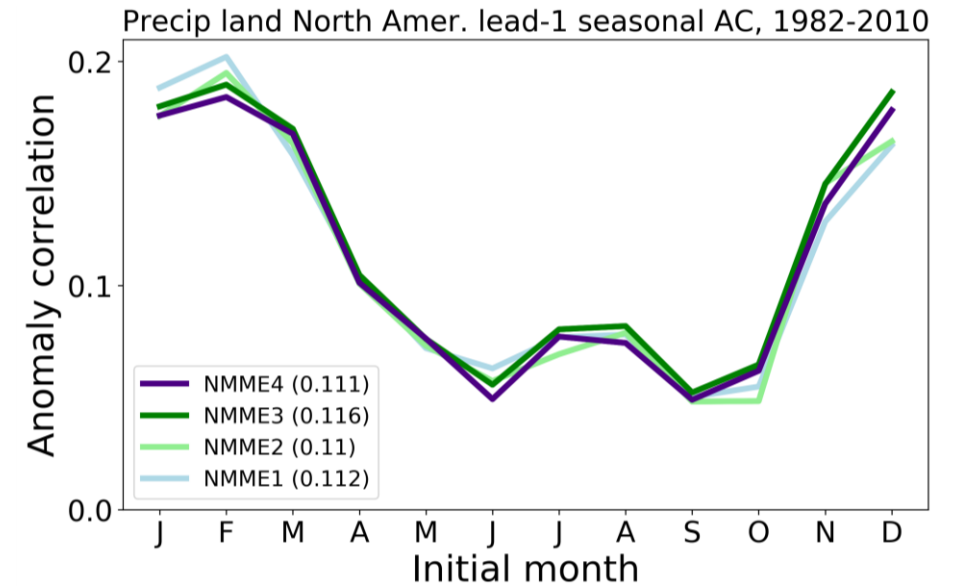


**RPSS Precipitation**  
North America – Day 19-25



# North American Multi-model Ensemble (NMME)

- Varies in Space and Time
- Low over North America
- No significant improvement



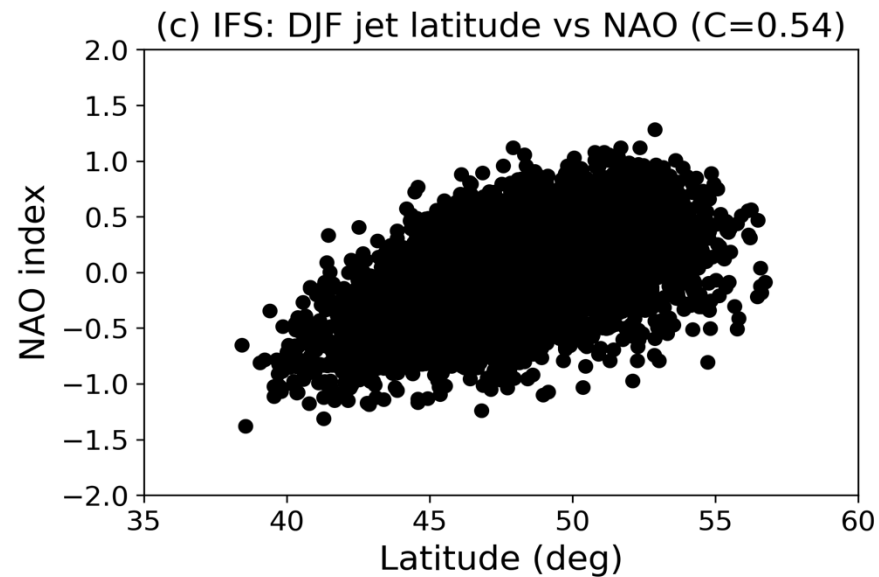
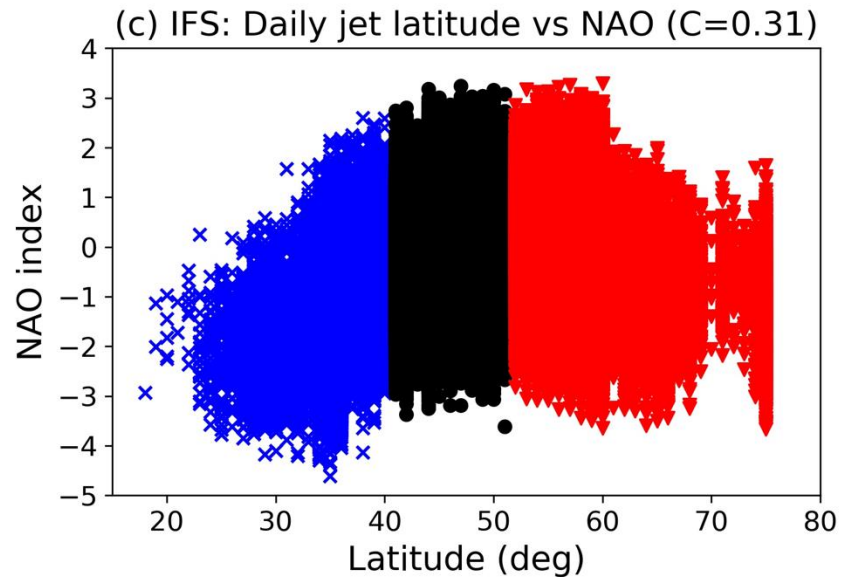
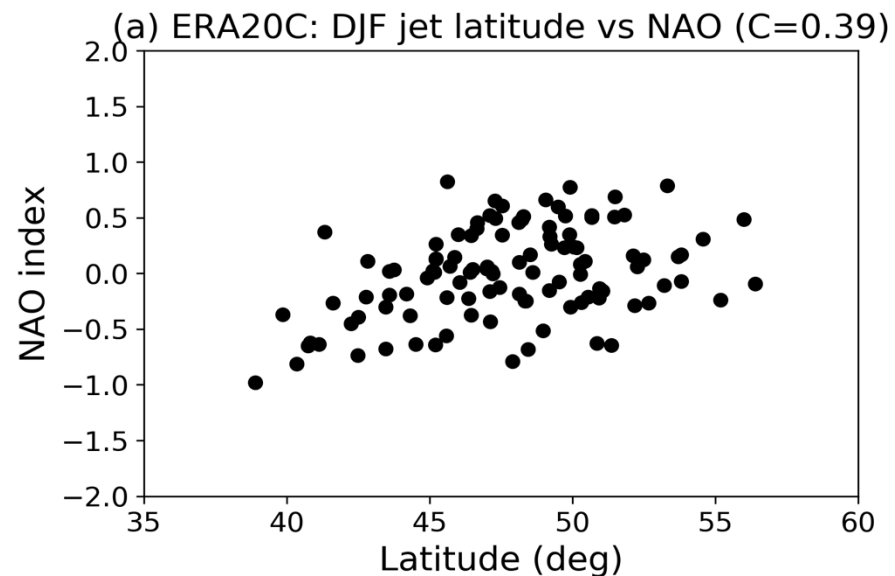
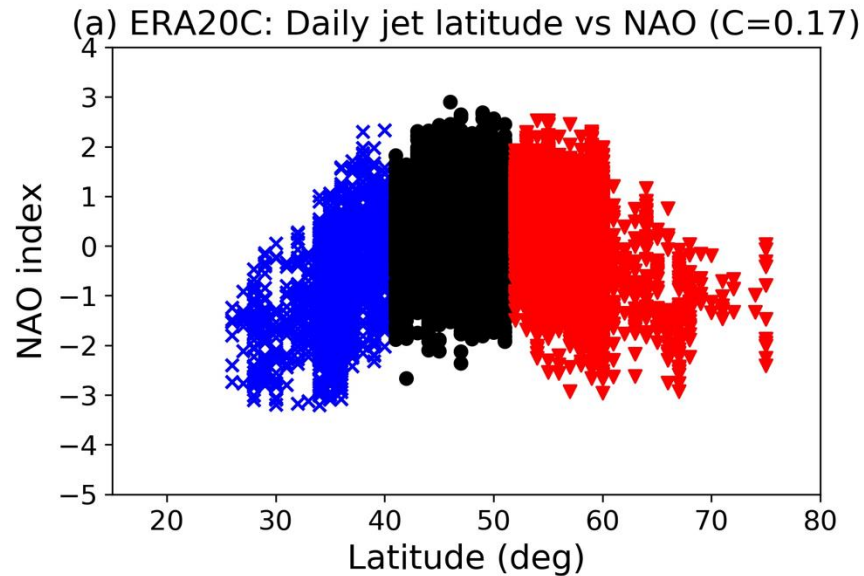
# Part I: Presentations

- Regime Dynamics and Eddy Forcing
  - Need High Temporal Resolution (at least daily)
  - Need large ensemble to cope with low signal/noise ratios
- Model errors limit teleconnections and regimes, predictability and prediction quality.
  - Phenomenological Interactions
- Need for Observations of fluxes, precipitation, humidity, and in general for those variables that reanalysis do not do well.

# Panel Discussions

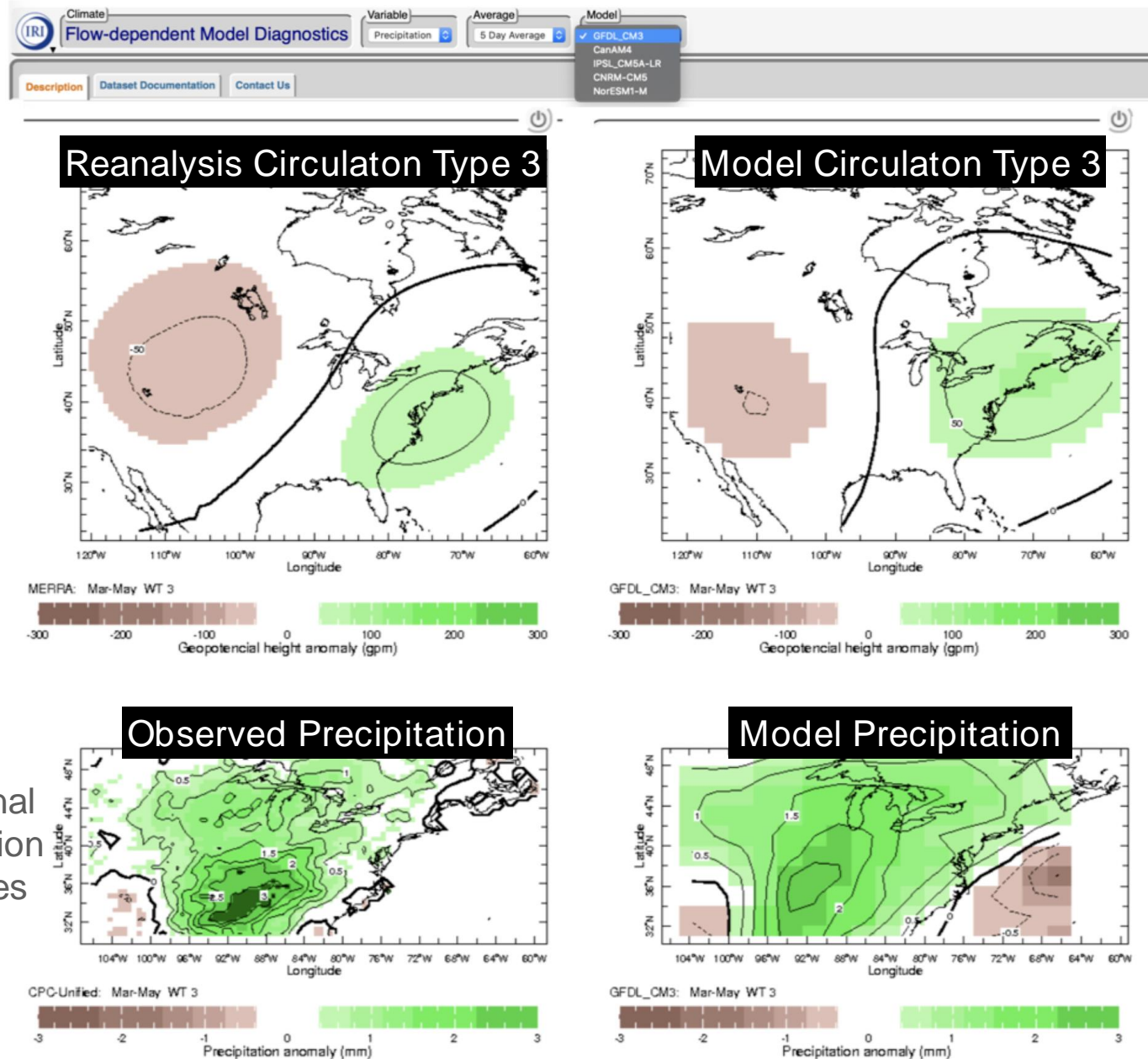
- Importance of Process Level Understanding in the Component Models and Their Interactions
- Inadequate Observations vs. Inadequate Models
  - Observations Needed to Improve Models

## 2. Regime Dynamics



**Monthly/seasonal  
means smooths away  
important structure**

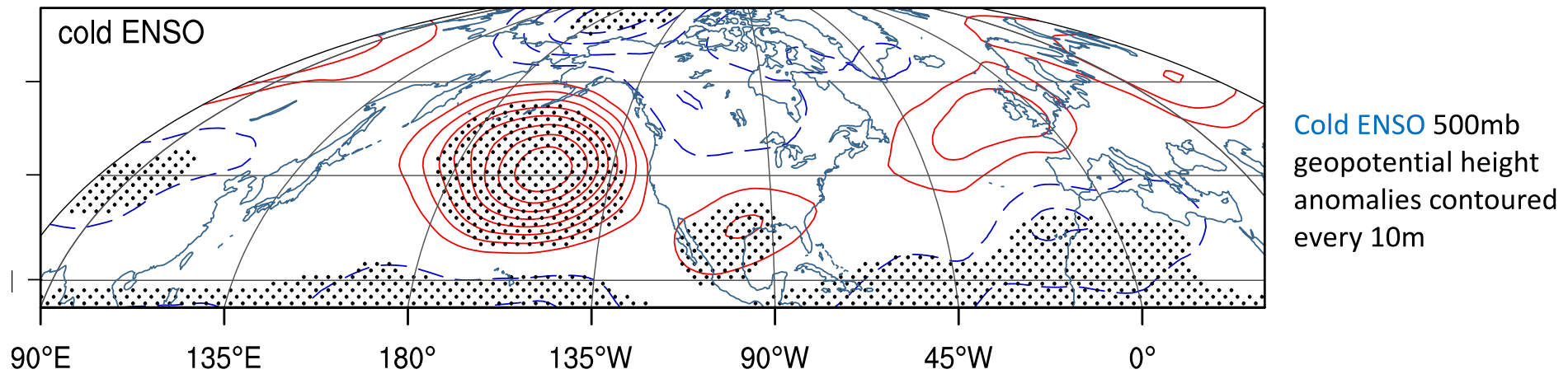
# Large-Scale Circulation Regimes: Systematic Errors



- Regional-scale precipitation is **synoptically controlled** by large-scale circulation patterns
- Model representations of these patterns often contain significant biases in structure

Ángel Muñoz, IRI  
AGU Poster

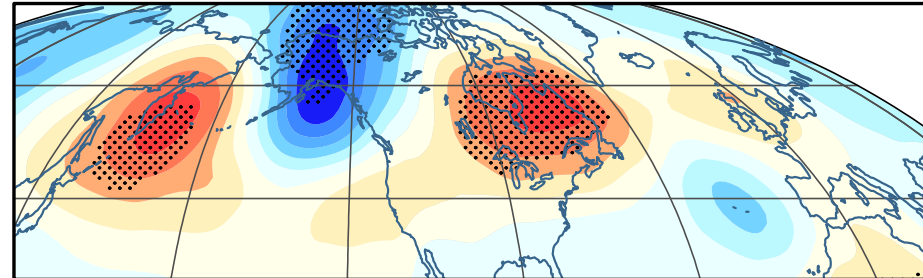
<http://iridl.ldeo.columbia.edu/maproom/Global/index.html>



## La Niña

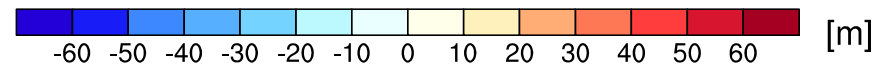
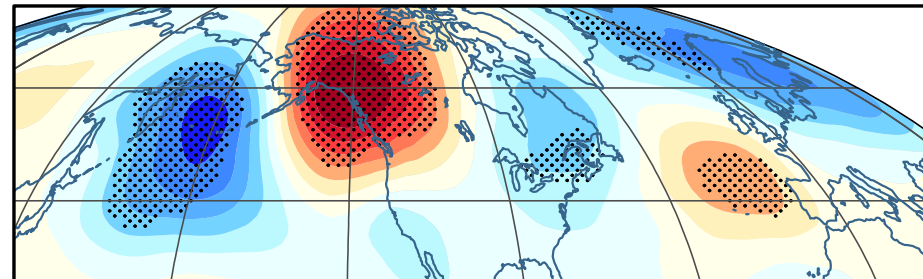
### 30-70 day filtered 500mb gph anomalies

5-9 days after MJO Phase 3 during cold ENSO



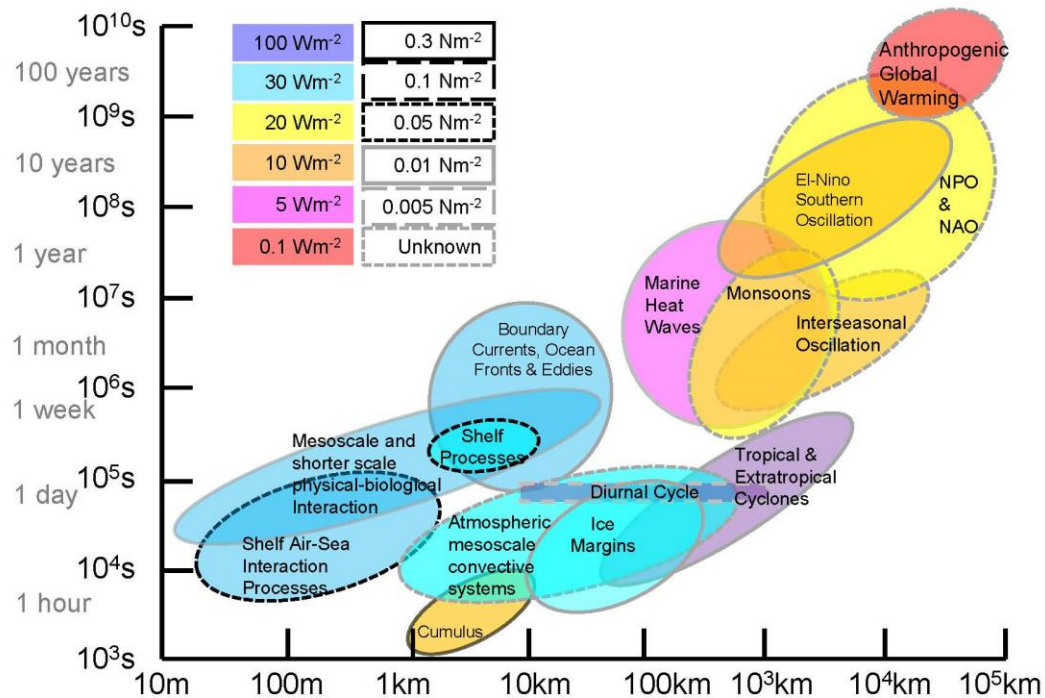
During La Niña, MJO  
teleconnections are  
shifted west due to a  
retracted subtropical jet

5-9 days after MJO Phase 7 during cold ENSO



# To predict weather and climate influenced by the ocean, we must accurately resolve air-sea heat fluxes

## Flux Accuracies and Processes



Cronin et al. (2019) "Air-sea fluxes with a focus on heat and momentum"

*How accurate?*

*What resolution?*

*Where are these observations needed?*

*How can this be done?*

**An Observing Air-Sea Interactions Strategy (OASIS) for 2030**

# Part II: Presentations

- Need Better Estimates of Predictability
  - Model Error
- Better Tropics - Better Mid-Latitudes
- Forecasts of Opportunity
- Robust Interactions among Weather and Climate Prediction Communities
- Coupling A-O (Ocean Fronts) and A-L (Soil Moisture ...)
- Resolution: Process or Phenomenologically Driven
- Empirical Bias Corrections

# Panel Discussions

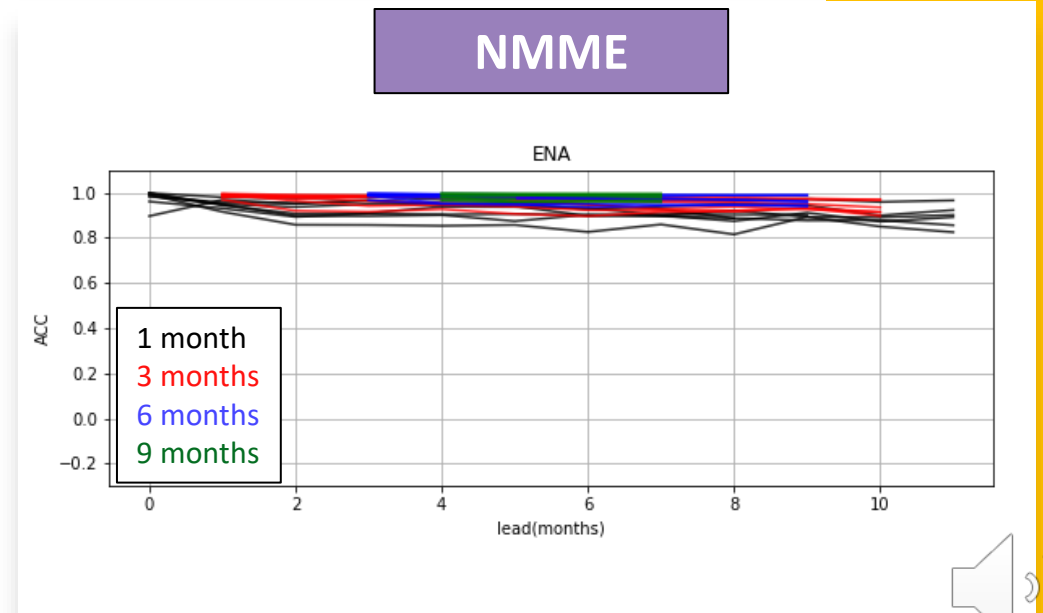
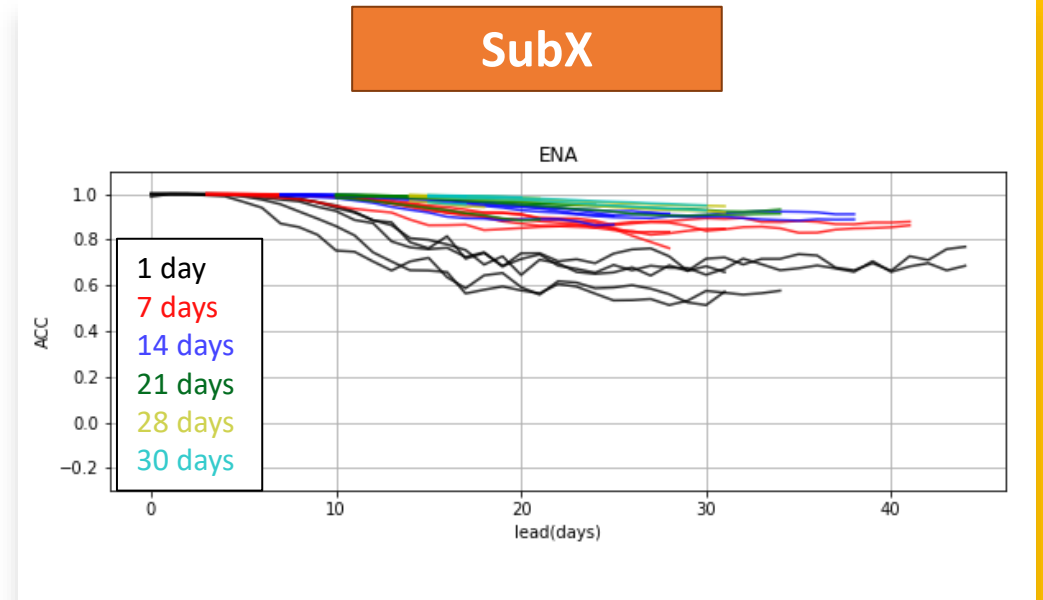
- Low Hanging Fruit for Improving Predictions over the Next 5-years?
  - Resolution, High-Resolution Refinement, Large Ensembles, Machine Learning, Identifying which Model Biases Actual Affect Forecast Skill, Improved DA, Holistic Approach
- Organize effective model developments and exploit computer resources
  - Too Many Sub-Critical Efforts, More Collaboration/interaction Among WX and Climate Communities, Forecast Use, Seamlessness
- Advances in the last 10-20 years? Any break-through? Or slow step by step?
  - Significant Reduction in Biases, ENSO, Arctic Sea-Ice
- Precipitation types?
  - Very High-Resolution DA, Micro-physics Not Currently Well Represented, Aerosols, Higher Frequency Outputs,

# We do not know the upper limit of skill

Unrealistic estimates

Noise is large at these timescales

Understand predictability by understanding signal



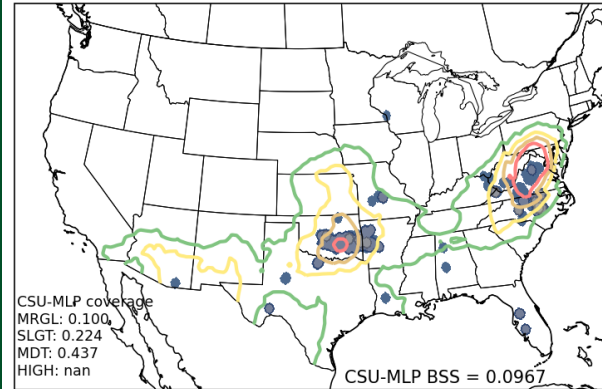
We know that post-processing of numerical model output (using machine learning or other techniques) works well for the short range through the medium range

How far can these methods extend the skill? What new methods can be developed for S2S timescales?

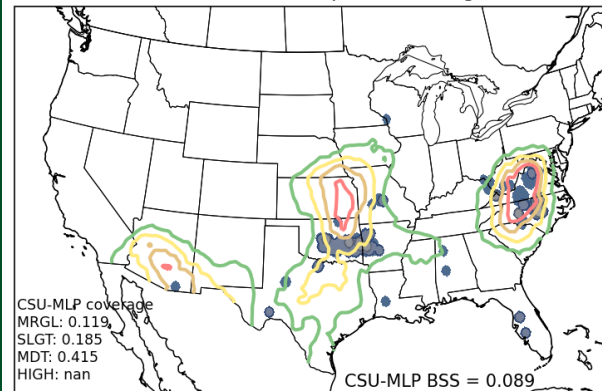
Based on Herman et al. (2018a,b)

## CSU-MLP forecasts & obs

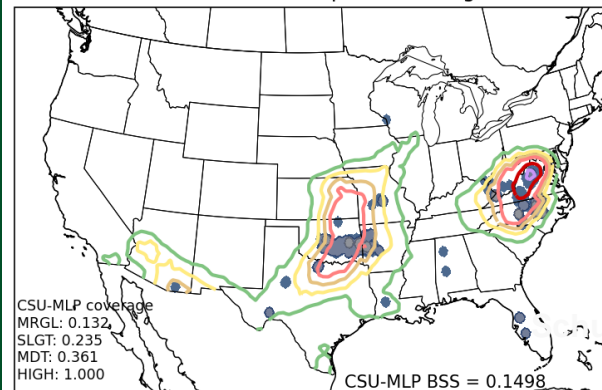
CSU-MLP day3 & UFVS obs  
issued 2020082900 for 24-hr period ending 2020090112



CSU-MLP day2 & UFVS obs  
issued 2020083000 for 24-hr period ending 2020090112

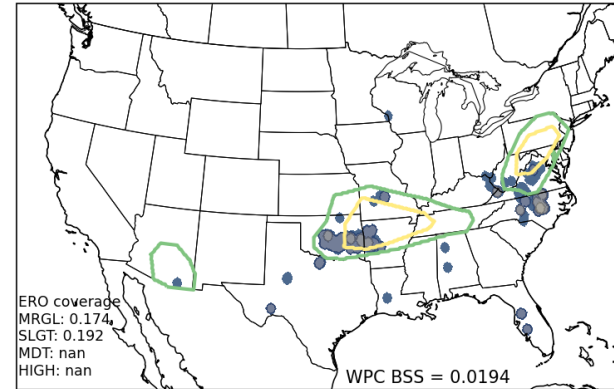


CSU-MLP day1 & UFVS obs  
issued 2020083100 for 24-hr period ending 2020090112

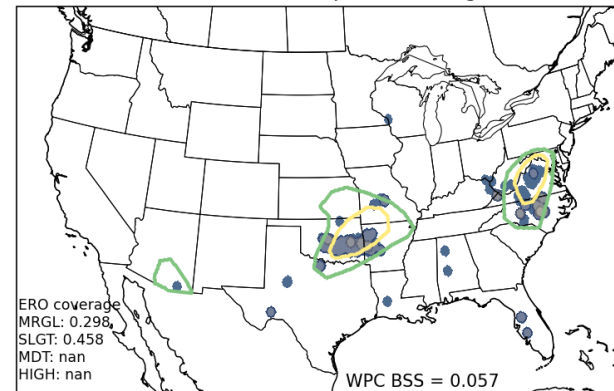


## WPC forecasts & obs

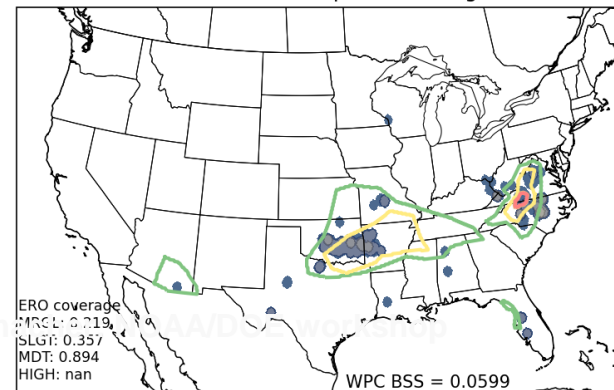
WPC ERO day3 & UFVS obs  
issued 2020082909 for 24-hr period ending 2020090112



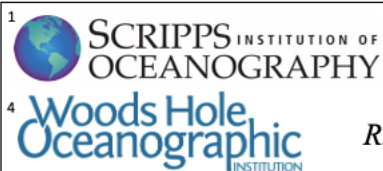
WPC ERO day2 & UFVS obs  
issued 2020083009 for 24-hr period ending 2020090112



WPC ERO day1 & UFVS obs  
issued 2020083109 for 24-hr period ending 2020090112



# Coupled atmosphere-wave-ocean-land interactions can influence precipitation drivers



## Investigating atmosphere–ocean–wave interactions and mesoscale features in atmospheric river events using a regional coupled model

R. Sun<sup>1,2</sup>, A. Subramanian<sup>1,2</sup>, B. D. Cornuelle<sup>1,2</sup>, I. Hoteit<sup>3</sup>, M. Mazloff<sup>1</sup>, A. J. Miller<sup>1</sup>, F. M. Ralph<sup>1,2</sup>, H. Seo<sup>4</sup>



Ocean coupling helped improve Atmospheric river forecasts when mean SST was cool

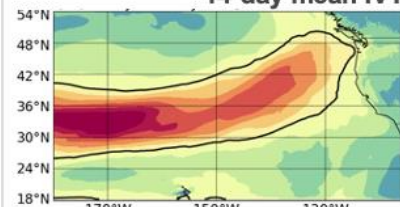
Exciting new project: Earthworks aims to run all component models on a single enormous grid



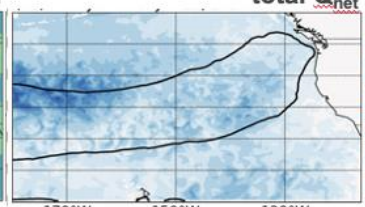
Earthworks  
Global Storm Resolving Model

Can improved coupling across components increase prediction skill?

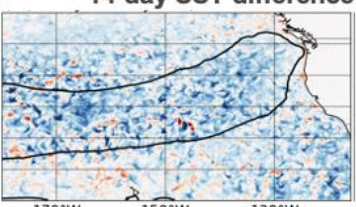
Case1, strong cooling AR, Jan 07 to Jan 21, 2018  
14-day mean IVT



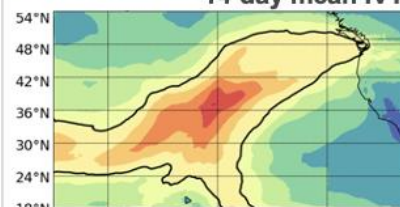
total  $Q_{net}$



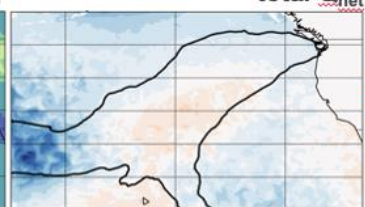
14-day SST difference



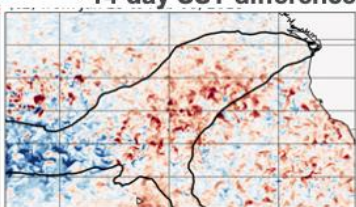
Case2, weak cooling AR, Jan 25 to Feb 08, 2018  
14-day mean IVT



total  $Q_{net}$

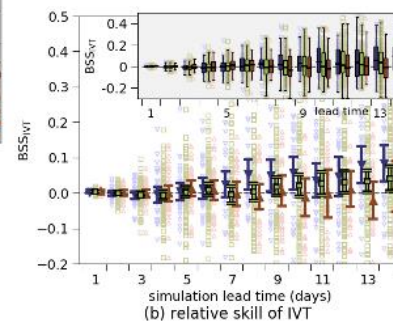
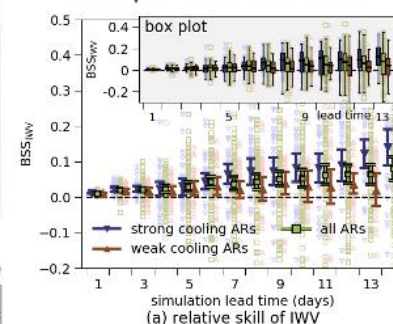


14-day SST difference



We use the Scripps–KAUST Regional Integrated Prediction System (SKRIPS) modeling framework available at [https://github.com/iurnus/scripps\\_kaust\\_model](https://github.com/iurnus/scripps_kaust_model)

Comparison of the skill



### ARTICLE

## Ocean Fronts and Eddies Remotely Forcing Atmospheric Rivers and Heavy Precipitation

> Xue Liu, Xiaohui Ma, Ping Chang, Yinglai Jia, Dan Fu, Guangzhi Xu, Lixin Wu, R. Saravanan, Christina Patricola

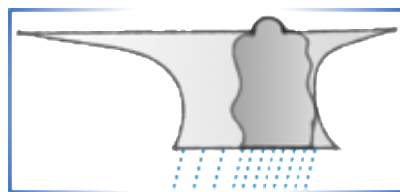
DOI: 10.21203/rs.3.rs-82364/v1 Download PDF

# Soil moisture-precipitation feedback as an amplifier of precipitation error and limits of precipitation predictability

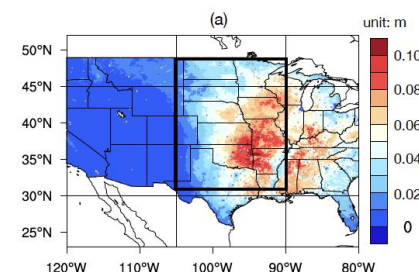
Models that simulate fewer / weaker MCSs in early warm season may have larger biases in simulating summer precipitation by breaking the soil moisture-precipitation feedback

## Inferences from numerical tracer experiments that tag the transit of water associated with MCS and non-MCS rainfall

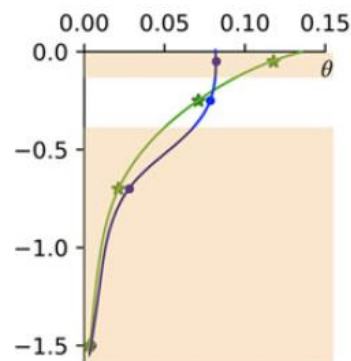
MCS produces more intense rain with larger rain area



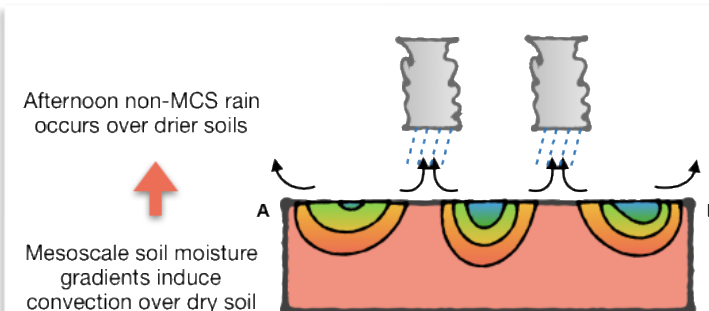
MCS rain produces larger soil moisture anomalies with stronger gradients



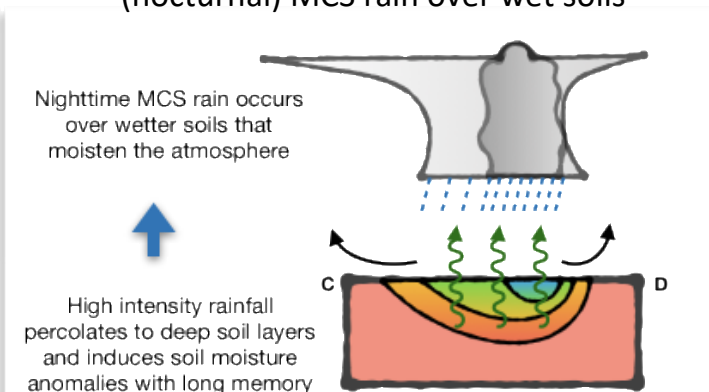
MCS rain percolates deeper in the soil layers with longer memory



Earlier season MCS rain favors summer (afternoon) non-MCS rain over dry soils



Earlier season MCS rain favors summer (nocturnal) MCS rain over wet soils

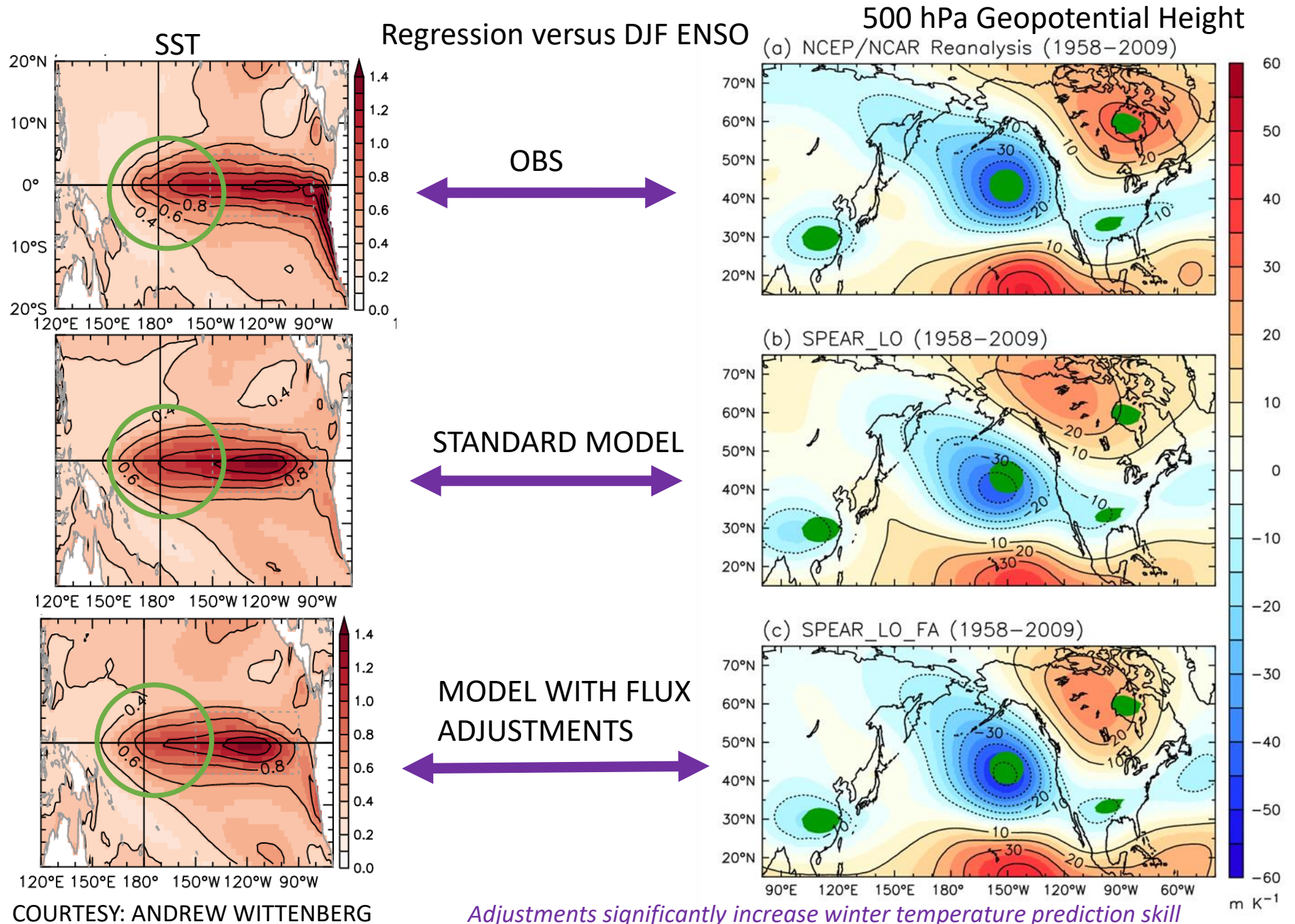


Hu, H., L.R. Leung, and Z. Feng. 2020. "Observed Warm-Season Characteristics of MCS and non-MCS Rainfall and Their Recent Changes in the Central United States." *Geophys. Res. Lett.*, 47, doi:10.1029/2019GL086783.

Hu, H., L.R. Leung, and Z. Feng. 2020. "Understanding the Distinct Impacts of MCS and Non-MCS Rainfall on the Surface Water Balance in the Central US Using a Numerical Water-Tagging Technique." *J. Hydrometeor.*, 21, 2343-2357, doi:10.1175/JHM-D-20-0081.1.

Hu, H., L.R. Leung, and Z. Feng. 2020. "Earlier-Season Mesoscale Convective Systems Dominate Soil Moisture-Precipitation Feedback for Summer Rainfall in Central US." Submitted.

In parallel with fundamental advancements, artificial bias reduction techniques may yield useful insights



# Key Points: Potential Paths Foreword

- Large-scale weather regime-based approach
- Resolving multi-scale processes
- Local feedbacks such as land-surface as potential source of predictability.
- Unified or Seamless modeling
- Machine Learning for a Range of Applications
- Systematic investigations of impacts of model bias
- Tropical heating as source of predictability
- Stakeholders/users engagement
- Improved understanding and representation of air-sea coupling
- Moisture profile observations are critical for correct initialization.
- More innovative ways of evaluating precipitation processes and types